BIG TECHNOLOGY, THE TECHNOLOGY GAP, AND A DANGEROUS POLICY PITFALL

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March 1968

P-3795

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Over the past few years, inadvertently, the Europeans appear to have p... ented the proponents of big science with a windfall. Europeans have pointed with alarm to an alleged technology gap between themselves and the United States, have credited (or blamed) the gap on massive support of "big science and technology" by the United States government, and have proposed that the remedy is for European governments to do likewise. If their arguments are heeded big science on the continent is likely to benefit. So also is big science here, for surely no better argument can be presented for your own policies than their emulation by others.

In this paper I shall argue that while the technology gap certainly is real in a wide variety of fields, aside from defense and space it probably has far less to do with U.S. big science than many people think. Association of the economic progressivity of the U.S. with large government financed R&D programs may not only be mistaken,

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This paper was prepared for presentation at The Sixth Goddard Memorial Symposium held in Washington, D. C., March 4, 5, 1968, and was based on research undertaken under the sponsorship of the Twentieth Century Fund and the Agnelli Foundation and reported in an earlier paper: "The Technology Gap: Analysis and Appraisal," P-3694-1, The RAND Corporation, December 1967.

but may lead the Europeans to squandering of considerable resources that could be used better in other ways. And, if Americans do not watch out, we could be lured into a meaningless, but extremely expensive, technological race for its own sake.

I. ON THE MEANING AND EXISTENCE OF A TECHNOLOGICAL GAP

By a technological gap I think most people have in mind phenomena that transcend the consequences of differences across countries in factor endowments, either innate, or as developed through past investment. The operational part of the discussion of the technology gap appears to focus on better flow of knowledge of product or process, or of organization to exploit knowledge more effectively. While investment of various specific kinds -- R&D and high level technical education -- are involved in the discussion, closing the technological gap is not generally assumed to require massive transfer or application of resources.

Thus, differences in output per worker is not direct evidence that a technological gap exists between the high and lower productivity countries. Various studies of cross country productivity differences indicate strongly that differences in investment are a good part of the story.* Both physical capital per worker, and various measures of educational attainment, are systematically related to output per worker. But various other studies indicate quite strongly that there is more to it than this.**

It has been known for some time that if one looks at growth over time within a country, increases in capital per worker (even including education and other forms of human capital) are incapable of fully explaining growth of productivity, and obviously cannot

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*See Kenneth Arrow, et al., "Capital Labor Substitution and Economic Efficiency," The Review of Economics and Statistics, August 1961.

**See Richard R. Nelson, "International Productivity Differences in Manufacturing Industry: Problems with Existing Theory and Some Suggestions for a Theoretical Restructuring," P-3720-1, The RAND Corporation, January 1968.

come to grips with the phenomena even more impressive than productivity growth -- the tremendous enrichment and improvement in the kinds of final products produced.[*] Recent research by Keesing, Vernon, Hufbauer, and others, has been concerned with the effect of technology and technological change on trade patterns.[**] Their well-known results are that, to a considerable extent, U.S. manufacturing exports are in new products that other countries have not yet begun to produce in quantity. Vernon and Hufbauer go on to show that, with a lag, other manufacturing nations pick up and employ U.S. technology and gradually cut the United States out of export markets.

But putting these threads together one comes up with an explanation of international differences in productivity that involves but transcends differences in capital. The main engine of manufacturing development is the creation of new technological knowledge, and its application, above all in the United States, and to a more limited extent in Europe and Japan. With a lag, the other major manufacturing countries pick up the new technology and learn to use it effectively. With a much greater lag, the less-developed countries do. Under this view, one would expect to find differences across countries in the productivity and composition of manufacturing activity that transcend

[*] For a review of the literature see Richard R. Nelson, Merton J. Peck, and Edward D. Kalachek, Technology, Economic Growth, and Public Policy, The Brookings Institution, Washington, D. C., 1967.

[**] Donald Keesing, "The Impact of Research and Development on U.S. Trade," Journal of Political Economy, February 1967; Raymond Vernon, "International Investment and International Trade in Product Cycles," Quarterly Journal of Economics, June 1966; G. C. Hufbauer, Synthetic Materials and the Theory of International Trade, Gerald Duckworth, 1966.

differences in capital and other inputs per worker directly engaged in production.

This clearly is the complex of phenomena that the Europeans are talking about. Note that a technological gap, in this sense, should show up in three ways. The first is differences in total factor productivity, which probably will be associated with differences in output per worker but transcends it. Second, one should observe that the leading country is a major exporter in technically progressive industries. Third, the lagging countries should be adopters of technology rather than innovators. The Europeans are concerned not only about the first of these, but also the other two.*

A technology gap, characterized as above, could be the result of a lot of factors. Much of recent European discussion has focused on one -- a big science gap.**

*That a "productivity gap" exists is documented in Edward Denison (assisted by Jean-Pierre Poullier), Why Economic Growth Rates Differ, The Brookings Institution, 1967.

**In particular, see P. Cognard, Recherche Scientifique et Independence, Bruxelles, October 27, 1964, and other writings by Cognard.

II. THE TECHNOLOGY GAP AS A LONG STANDING PHENOMENA

One of the reasons for identification of "big science" as the source of the gap is the belief that the gap is a recent phenomenon. But it is not. As long ago as 1835 de Tocqueville noted:

> The United States of America has only been emancipated for half a century from the state of colonial dependence in which it stood to Great Britain; the number of large fortunes there is small and capital is still scarce. Yet no people in the world have made such rapid progress in trade and manufactures as the Americans....*

Habakuk opens his excellent recent work on American and British Technology in the Nineteenth Century by confirming and reinforcing de Tocqueville's judgment.

> There is a substantial body of comment, by English visitors to America in the first half of the nineteenth century, which suggests that, in a number of industries, American equipment was, in some sense, superior to the English even at this period. As early as 1835 Cobden had noted, in the machine shop of a woollen mill at Lowell, "a number of machines and contrivances for abridging labour greater than at Sharp and Robers." He thought agricultural implements in New England exhibited "remarkable evidences of ingenuity...for aiding and abridging human as well as brute labour," and gave several other instances. And the two groups of English technicians who visited America in the 1850s reported that the Americans produced by more highly mechanised and more standardised methods a wide range of products including doors, furniture and other woodwork; boots and shoes; ploughs and mowing-machines, wood screws, files and nails; biscuits, locks, clocks, small arms, nuts and bolts.**

The evidence of a technological gap in many fields prior to 1850 essentially is the record of scattered non-quantitative impressions

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*Alexis de Tocqueville, Democracy in America, Vintage Books, New York, 1955, Vol. II, pp. 165-166.

**H. J. Habakkuk, American and British Technology in the Nineteenth Century, Cambridge University Prers, 1962, pp. 4-5.

of sophisticated and knowledgeable visitors. After 1850 we have access to more quantitative evidence. All three facets were present; higher total factor productivity, a strong export position in technically progressive industries, and foreign (European) adoption of the U.S. practices.

It is very clear that by the 1860s and 1870s real per capita income was significantly higher in the United States than in the United Kingdom or Western Europe. Kuznet's data show that, if anything, the percentage difference between the United States and France and Germany was greater in the mid-nineteenth century than today, and the relative gap between the United States and England was only slightly smaller than that now.* In part this was due to the high productivity of American agriculture. But value added per worker almost certainly was higher in American manufacturing industry.

It was higher for at least two reasons. Even by that time a large number of industries in the United States probably were operating at a higher capital-labor ratio than their English or European counterparts. This is both explained by and explains the significantly higher wage rate in U.S. industry. High American wages go back at least as far as 1830, and scattered evidence suggests that by the 1870s U.S. wages may have averaged perhaps twice that in the United Kingdom (and even more, relative to France and Germany). But this cannot be the full explanation. If it were simply greater capital intensity, but the same total factor productivity, the rate of return

*Simon Kuznets, Modern Economic Growth, Yale University Press, 1966, pp. 64, 65.

on capital should have been significantly lower in the United States. The limited evidence suggests, rather, that it was higher. Over the second half of the nineteenth century the yield on British consols never got above 3.5 percent; the yield on the best American railway bonds (to be sure, somewhat more risky) never sunk that low and tended to be over 5.0 percent.* Relatedly, this was a period when capital was flowing from the United Kingdom to the United States, not the other way around.

Between 1880 and 1910 the growth of U.S. finished manufactured exports increased more than six fold; imports less than tripled. The United States, which ought to have and clearly did have a great comparative advantage and large net export position in foodstuffs (which made exchange available for manufactured imports) nonetheless was a net exporter of manufactured products by 1900. A good share of the surge was in "technically progressive" industries. By 1899 about one-third of U.S.-manufactured exports were in machinery, chemicals, or vehicles.** For Germany and the United Kingdom the figure was about one-fifth. The value of U.S. machinery exports increased ten-fold between the mid-1880s and 1905-1906. It would appear that around the turn of the century the United States dominated trade in typewriters, for example.***

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*William Fellner, <u>Trends and Cycles in Economic Activity</u>, Henry Holt and Company, 1956, pp. 396, 397.

**All data cited for U.S. exports during the late nineteenth and early twentieth centuries are from The Historical Statistics of the United States, U.S. Department of Commerce 1960.

***See the paper by Richard N. Cooper, In Technology and World Trade, U.S. Department of Commerce, 1967

This evidence suggests a significant "technological lead," not surprisingly, for the last half of the nineteenth century was indeed the well-known great age of American invention. It was also the era in which the system of interchangeable parts was rapidly coming into play in industry after industry in the United States. In many fields Europeans and Englishmen were busy picking up American technique with a lag, just as today. Of course it was not a one way street. The Americans did not lead in all fields, and in many fields the lead changed hands. Some time during the nineteenth century the U.S. lost its lead in shipping. The English and Europeans developed, and then lost to the Americans, the lead in steel technology. But that on the average, in some sense, the Americans were the technological leaders in manufacturing industry seems clear.

That a significant and widespread technological gap existed long before the age of big science spending in the United States certainly should cause at least some doubts regarding the facile explanation of "big science." However, the argument, powerful on the face of it, can be presented that the present cause of the gap is America's big science policy. While this is impossible to prove or disprove rigorously, there is a lot of reason to doubt it.

III. BIG SCIENCE AND THE PRESENT GAP -- A DUBIOUS CONNECTION

In another paper I pointed to the extreme importance of separating a "gap" regarding military technology, from a gap in capability to produce desired goods and services outside the military area.* I suggested that to a considerable degree the Europeans were worried about the former, more than the latter, but since they assigned the same cause to both, felt little need to distinguish the two.

The argument to which I refer, of course, is that the massive defense and space spending of the United States, and the (partially) associated giant size of the involved U.S. corporations, lies behind a general technology gap, not just a defense and space technology gap. Involved here are some assumptions about the nature of "spillover" and the role of corporate giants in the technical change process that, to say the least, require some skeptical scrutiny.

Obviously the U.S. lead in military technology is in good part the result of massive defense R&D spending by the U.S. government. Obviously also the knowledge, experience, and organization built up under defense and space R&D contracts has contributed to the U.S. capability to design and build commercial aircraft, has in some respects facilitated the evolution of non military computer technology, has had a diffuse if possibly important effect on the ability of U.S. companies to employ certain widely useful process techniques, and has influenced a few other fields. However, as shown above, the American technological lead long predated this government defense and space R&D spending. Even more important, it is highly doubtful that the

*P-3694-1, <u>ibid</u>.

spillover from defense and space R&D is a particularly important factor explaining the American technological lead in recent years except in a quite narrow range of fields.

This does not appear to be the place to review the various studies of spillover. Suffice it to say that the list of clean cut direct spillover examples is not impressive, only a very small percentage of patents resulting from defense and space R&D have ever been used commercially, and scattered interviews with executives of companies engaged in both defense and civilian market activities do not in general indicate a striking benefit to the latter from the former. Even in the fields of aircraft and computers, where the spillover is assumed to be large and direct, there is reason to believe that the direct transferabilities of the results of military R&D to civilian design is not as direct as might be believed.*

If spillover is limited t far from being close complements, actions to close the military technology gap and the civilian technology gap may be substitutes. With given scientific and technical resources one must trade one off against the other. In the United States there certainly is a point of view that large defense and space R&D programs are hindering the ability of the United States to keep a general technological lead, not helping it. Just before the recent expression of European concern about the gap, the United States had begun to be concerned about it, or rather its pending loss. Some people viewed the villain in the piece as the large U.S.

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*For a review of the literature see Nelson, Peck, and Kalachek, ibid.

defense and space R&D program which preempted scientific and technical resources from civilian R&D. It was warned that in industry after industry the Europeans and Japanese, not burdened by such a massive unproductive use of R&D resources, were overtaking us.

Thus the Council of Economic Advisers reported in 1963:

> In recent years, there has been a dramatic increase in total expenditures on research and development and in the number of scientists and engineers engaged in these activities. However, defense and space efforts have accounted for nearly three-fourths of the increase. The research laboratories of industry and the universities have been important sources of new products and processes for the civilian economy, but most private research and development is still concentrated in a relatively few industries and is carried on by a few large firms. With the exception of a few hundred manufacturing firms most enterprises neither undertake much research and development nor have sufficient trained technical manpower to take advantage of the research and development done by others. Our economy would be strengthened significantly over the long run if our civilian research and development resources were expanded to meet better the wide range of private and public needs.*

The role of the American corporate giants in the creation and application of new civilian technology is another phenomenon that often seems to be both exaggerated and misspecified. There is no denying the extremely important role played by the giant firms in many fields. There are many reasons why, in certain situations at least, giant corporations have a strong advantage in doing what is needed to advance technology, and why, in some circumstances, small or even medium sized firms simply cannot do the job. One important reason is that, sometimes, the size of the required R&D effort, its

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*<u>Economic Report of the President</u> together with <u>The Annual Report of the Council of Economic Advisers</u>, transmitted to the Congress January 1963, U.S. Government Printing Office, Washington, 1963, p. 63.

cost, and the cost of the investment and other activities needed to bring into operation the new technology or product, simply transcend the resources of any but giant firms. This has been predominantly the case in many areas of postwar military technology. It takes an extremely large firm to develop the principal components of modern missile and aircraft systems. European experience with these systems, as well as certain other perceived advantages of the American corporate giants, certainly has conditioned a belief in the advantages of size.

But it is easy to generalize falsely from missile systems to civilian technology, and from some areas of civilian technology (large commercial aircraft) to civilian technology in general. It simply is not so that in all, or most, fields, the costs of inventing, developing, and introducing technology are all that great. Reflecting this, in almost all product fields small companies have played an extremely important role in investing, developing, and introducing new technology. The study by Jewkes, Sawers and Stillerman documents this convincingly up to about 1950.* There is no comparable comprehensive study that examines the post 1950 period, but certainly in electronics the small and medium size companies have continued to be important sources of new technology.

However, the right way to pose the issue is not the contribution of the corporate giants versus smaller firms and individual inventors. To a considerable extent firms of different sizes do different things.

*John Jewkes, Davis Sawers, and Richard Stillerman, The Sources of Invention, Macmillan, 1958.

In most industries there is a wide menu of important R&D work to be done, some projects involving much higher costs than others. Obviously it takes a large company to undertake really expensive R&D projects (like developing a supersonic aircraft). But evidence seems to suggest that where R&D costs are not particularly high (generally for smaller scale systems) the small and medium size firm subsector of an industry is at least as likely to be technologically progressive as the giants of the industry. Further, costs and uncertainties differ at different stages of the R&D process. Very often the relatively low cost but high risk early exploratory work is initiated by a small company, with the subsequent high cost, lower risk development taken over by a larger company. The Whittle jet engine is an excellent case in point. And many of Duponts most important product innovations represented development of work initially done outside of Dupont by smaller companies.

In the United States, as contrasted with Europe, there has been growing concern that industries dominated by the giants may become technologically stagnant. During 1965 a series of hearings before the U.S. Senate subcommittee on Anti-trust and Monopoly was focused on just this.* In particular, the loss of American leadership in steel technology has been ascribed to the comfortable oligopoly structure that the large companies have developed for themselves.

*Economic Concentration, Hearings Before the Subcommittee on Antitrust and Monopoly of the Committee on the Judiciary, United States Senate, Part 3, Concentration, Invention, and Innovation, May 18, 24, 25, 27, and June 17, 1965.

IV. THE POTENTIAL DANGERS OF A "TECHNOLOGY GAP" POINT OF VIEW PER SE

I do not have the time here to try to suggest all of the factors that lie behind the long run progressivity of the bulk of American industry. However one in particular seems important to discuss, for to the extent it is important, there are reasons to believe that an active and widespread "big science policy," pursued either by the Europeans, or by us, may hinder, not help, achievement of the kinds of technological advances with the greatest social value.

From the beginning, economic policy making in the United States has been marked by a belief in the importance of business firms testing the value of their products on the market, in competition as a carrot and a stick for generating progress in products and processes, and in the mobility of resources. While sometimes this has amounted to lip service and from time to time policy has been dominated by particular business interests, by and large there has been little of public specification of the technological advances people "ought" to want, or of protecting particular business entities from competition, or of protecting the work force from frictional or structural unemployment. There has been considerable concern that new ideas and new firms have a chance to enter and compete. This, of course, did not apply to areas of public demand, like defense, public health, etc. And in certain generally private fields, like agriculture, government had a much more active R&D policy. But by and large the government limited its active R&D policy to "public sector" areas.

In another place I have argued strongly that the government undoubtedly should increase its R&D support in many non defense public sector related fields.* But this is far from saying that it is a sensible thing for government to think of substituting its R&D support for private initiative across the board.

Yet to a considerable extent much of recent thinking in Europe, associated with the gap discussion, carries the thrust of substituting a considerable measure of direct government R&D spending or directed support of private R&D, complementing an evolved form of economic planning, for private competition. While the exact nature of the proposed policies are often ambiguous, in some sense the proposal seems to amount to developing an economy-wide system with many elements in common to the system that has been adopted in the United States regarding defense and space.

It is clear that an active policy toward science and technology is much more important now than years ago. Technological advance in most industries today is much more closely linked to formal R&D than was the case years ago. In turn, both the supply of formally trained scientists and engineers, and the basic science efforts of the country are vastly more important. Both of these must be of central concern to government. And both the magnitude and allocation of government support of technical and scientific education and of basic research will profoundly effect the rate and direction of technological change. If the government could afford in the past not to have an active policy

*Nelson, Peck and Kalachek, ibid.

toward science and technology, this is no longer the case today.

However, it is not at all clear just what the dimensions and characteristics of an active science and technology policy should be. It most certainly should involve more than the strict neutrality with respect to the magnitude and allocation of industrial R&D that has marked the U.S. experience until recently. I suspect it should involve considerably less than the degree of government planning and support than the U.S. now has in defense and space. This has proved a good system for achieving rapid technological advance in a relatively narrow and well defined area, but it has been extremely costly.

The notion of government sponsoring of civilian R&D, and the role of competition versus a chosen instrument, are, of course, closely related. If the government directly supports particular industrial R&D projects in particular companies or groups of companies -- as it has in the United States in defense -- the role of competition is greatly diluted. Implicitly if not explicitly the favored companies are chosen instruments. Their success or failure cannot be a matter of indifference to government.

Several of the European nations may be approaching this kind of policy. The results I suspect will be much higher R&D costs, less valuable results to society, and erosion of many of the benefits of competition. Happily, the United States still is a long way away from such a policy.

However, there are present dangers regarding the direction of U.S. policy that can evolve quite rapidly. Inherent in much of the "gap" discussion is the notion that it is dangerous to let another

country get ahead of you technologically. Clearly this is so in strongly military related fields. But I suspect the lines will be drawn increasingly broadly. This can, and already has begun to, evolve into a policy of technology for technology's own sake. We are likely to see many more episodes like that of the supersonic transport where the principal rationale on both sides of the Atlantic has been based largely on advanced-technology-is-important-per-se type arguments, or on the argument that the other side was doing it, or planning to, and therefore we had better do it.

Again, I am not arguing against government support of various kinds of R&D. As I said, I suspect that a significant increase in public R&D is highly desirable, aimed at important national problems (like smog, the high cost of low cost housing, urban congestion, etc.), and at fostering the advance of promising areas of science and technology through support of basic research and experimental developments of various sorts. It is because I believe this, and also that private R&D spending, induced by the market through traditional mechanisms, also has a high social rate of return, that I am disturbed by the trends I see. If we squander our scientific and technical resources in technological races for their own sake, we may have little left to allocate to the more tangible interests of mankind.